Annual Report on NAG3-2341
Sheet Flows, Avalanches, and Dune Evolution on Earth and Mars
February 2000 through November 2003

This investigation is a collaboration between researchers at Cornell University, the University of Florida, and the University of Rennes 1, France.

Flow modeling at Cornell University focused on mechanisms for the suspension and transport of wind-blown sand that are important in both terrestrial and Martian environments. These mechanisms include the saltation (or jumping) of grains, collisions between grains, and the interaction of grains with the velocity fluctuations of the turbulent wind. Of particular interest are sheet flows; these are relatively thin, highly concentrated regions of grains flowing near the ground under the influence of a strong turbulent wind. In them, the grains are suspended by interparticle collisions. Sheet flows may be relatively rare events, but they have the capacity to move great amounts of sand.

In order to describe sheet flows, a turbulent mixture theory was formulated for particles in a fluid in which fluctuations in the volume fraction of the particles take place on the scale of the turbulent eddies. Ensemble averaged equations for particle and fluid mass, momentum, and energy and fluid rate of dissipation were expressed in terms of Farve (concentration) averaged velocities and the associated velocity fluctuations. Correlations that describe the turbulent suspension of particles and dissipation of turbulent energy of both phases due to fluid particle interactions were modeled and boundary conditions at the bed and at the upper surface of the collisional flow were formulated. The boundary conditions at the upper surface were tested in a numerical simulation developed at the University of Florida.

Steady and unsteady solutions for steady and unsteady fully-developed flows were obtained over a range of wind speeds from the lowest for which collisional between particles occurred to at which turbulent suspension is found to dominate collisional suspension. Below the value of the wind speed at which collisions between particles were unimportant, numerical solutions were obtained for the velocity distribution function and the resulting fields of concentration, particle and gas mean velocity, and particle shear stress for the steady two-dimensional saltation of spherical sand particles driven by a turbulent wind over a bed characterized by a simple relationship (the splash function) between the properties of incoming particles and those of the rebounding particles and other particles ejected from the bed.

At the University of Rennes 1, experiments devoted to the characterization of the splash function for beds consisting of either random or ordered arrays of spheres in two-dimensions were completed. These indicated the role played by the packing geometry in the rebound and ejection of grains. Preliminary experiments on response of a three-dimensional collision bed to a collision with a single particle were performed. Data was taken with a single camera focused on the plane of collision. Here, for example, the decrease of the effective coefficient of restitution of the bed with an increase of the angle of incidence of the incoming particle has been measured.

Other experiments on avalanches at Rennes studied the properties of the flows of particles that are responsible for the motion of the leeward side of a dune. In these, the dependence of the initiation of avalanches on the packing and depth of the particles was measured. Particle migration was studied in inclined flows of a binary mixture of disks and the mechanisms of diffusion and segregation were isolated and characterized. The influence of side wall on dense, rapid inclined flows was measured and shown to be the reason why the angle of the free surface in such flows can exceed the static angle of repose.

Future research will be devoted to a better understanding the transition between saltating (collisionless) and collisional flows as the wind speed the increases. This will involve the understanding of the evolution of the splash function as collisions with the bed become more numerous, more frequent, and more violent.

Publications:

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Thesis:
Beladjine, D. (2003) Experimental study of the three-dimensional splash process in aeolian sand transport, Masters Thesis, University of Rennes 1.

Talks:
J. T. Jenkins: "On Collisional and Aeolian Flow"
Department of Applied Mathematics and Theoretical Physics
Cambridge University, November 7, 2003

J. T. Jenkins "On Collisional and Aeolian Flow"
Department of Mathematics
Bristol University, November 28, 2003

D. M. Hanes, "Wave induced sheet flows: Measurements and models",
Workshop on Flow Regimes, Transitions, and Segregation in Granular and Particle-Laden Flows
Isaac Newton Institute workshop on granular flows, Cambridge, United Kingdom, October, 2003.

J. M. Pasini "Transition from saltation to sheet flow in aeolian sediment transport"
Workshop on Flow Regimes, Transitions, and Segregation in Granular and Particle-Laden Flows
Isaac Newton Institute, Cambridge University, September 22-26, 2003

R. Delannay "Segregation in 2D inclined chute flows"
Workshop on Flow Regimes, Transitions, and Segregation in Granular and Particle-Laden Flows
Isaac Newton Institute, Cambridge University, September 22-26, 2003

N. Taberlet "A super-stable granular heap in a thin channel"
Workshop on Flow Regimes, Transitions, and Segregation in Granular and Particle-Laden Flows
Isaac Newton Institute, Cambridge University, September 22-26, 2003

A. Valance "Sand ripples formation in a laminar boundary layer flow"
Workshop on Flow Regimes, Transitions, and Segregation in Granular and Particle-Laden Flows
Isaac Newton Institute, Cambridge University, September 22-26, 2003

D. M. Hanes, Nearshore Sediment Transport Using Two-phase Approach, Dean Conference, Gainesville, FL, November 2003.